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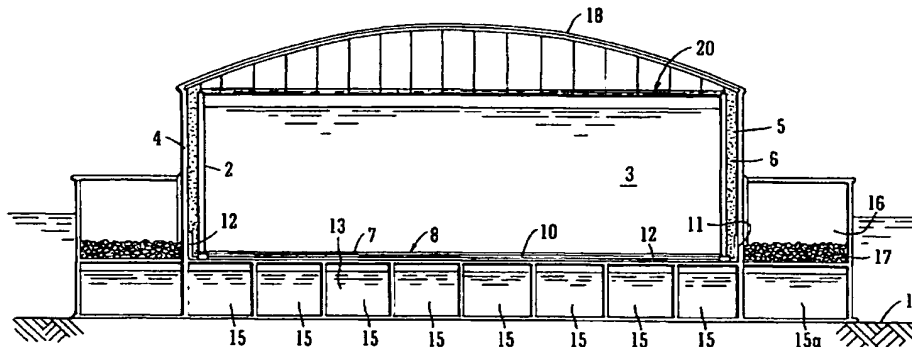
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(54) Title: LIQUEFIED HYDROCARBON GAS STORAGE TANK WITH UNLINED CONCRETE WALLS



(57) Abstract: A liquefied hydrocarbon gas storage structure is provided having inner (2) and outer (4) unlined concrete walls. The walls are formed by slipforming and are cyclindrical in form. The walls are post-tensioned to resist the pressure exerted by the gas stored in the tank. The inner wall can be arranged to be free to move relative to the outer wall. Further, the walls can ideally be formed simultaneously by slipforming and the roof of the structure is then erected after the walls have been completed.

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## LIQUEFIED HYDROCARBON GAS STORAGE TANK WITH UNLINED CONCRETE WALLS

5 The present invention relates to structures for storing  
liquefied hydrocarbon gases such as for example  
liquefied natural gas and, more specifically, to a  
liquefied hydrocarbon gas storage structure comprising  
an unlined concrete storage chamber.

10 Liquefied natural gas (LNG) has traditionally been  
stored on shore although several offshore storage  
terminal concepts have also been proposed in the  
technical literature in recent years. The preference to  
15 locate a terminal offshore rather than onshore has  
generally been driven by societal or political  
considerations rather than on purely economic grounds.  
To date, the costs associated with constructing offshore  
terminals have been estimated to be higher and the  
20 construction time schedules longer than for onshore  
terminals which has made the construction of offshore  
terminals less attractive.

Onshore LNG tanks have traditionally been procured from  
25 established tank vendors using Engineer, Procure and  
Construct contracts. In recent times, the majority of  
tanks have been specified as full containment designs  
with secondary containment provided by a cylindrical  
post-tensioned concrete structure in conjunction with  
30 either a steel or concrete roof. The design and  
construction of the civil components of the secondary  
containment structure has frequently been subcontracted.

Proprietary tank designs that have been developed for  
35 the primary containment of LNG include:

Cylindrical 9% nickel steel tanks; Prismatic aluminium

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tanks; Spherical aluminium tanks; Membrane tanks; and Lined concrete tanks.

5       Secondary containment structures for offshore LNG storage terminals will be constructed some distance from the installation site. Their design is less straightforward than for onshore facilities since hydrostatic and hydrodynamic loading must be considered in addition to operational conditions.

10       For an offshore receiving terminal, a key design choice is whether to integrate the primary containment within the support structure or whether to separate the functions of LNG containment and support.

15       Concepts have been developed which separate the LNG primary and secondary containment from the supporting structure. These can be classified as onshore concepts employed offshore, since the support structure  
20       essentially acts as an artificial island.

      Integrated designs have been proposed for fixed and floating offshore LNG facilities based on either membrane or prismatic primary containment systems within  
25       a concrete support structure.

      Steel secondary containment structures have been considered less frequently for bottom-founded structures, but are nonetheless feasible. The lower  
30       resilience of steel to fire and impact events compared to concrete must be addressed if steel receiving terminals are to achieve the same degree of robustness as onshore concrete full containment tanks.

35       Integration of the LNG primary containment structure within the support structure reduces the total quantity of structural materials. However, to gain the benefit

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of this integration, the following problems must be addressed:

- 5      i) preventing water penetration from the surrounding sea into the insulation space;
- ii) limiting the thermal strains to which the secondary containment is subjected;
- 10     iii) achieving a balance between providing an economic insulation system and maintaining the necessary heat flow into the tank to prevent sea-water freezing;
- 15     iv) achieving an efficient foundation design whilst minimising the overall structure height by submerging the tank further below the water line.

Regassification facilities must be provided on the storage terminal above the wave zone to prevent wave impact in operation. The overall height of some terminal concepts has been selected from considerations of wave impact and a flat roof has been provided over the storage area to support the facilities at height. Such facilities may be installed either at a quayside using land-based cranes, offshore using heavy-lift cranes, or by skidding across with the support structure ballasted down in an inshore location.

Quayside installation requires a deep-draughted berth to accommodate the structure, offshore lifting is costly and inshore skidding requires relatively deep sheltered conditions. Thus, none of these installation methods is particularly attractive or economic.

35     The present invention seeks to overcome the problems associated with the storage structures of the prior art by providing a structure which is relatively quick and

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cost effective to construct.

From a first aspect, the invention provides a liquefied hydrocarbon gas storage structure comprising an unlined concrete storage chamber.

As the storage chamber of the invention does not include liners such as conventional carbon steel liners or foil-based vapour barrier liners, the construction schedule for the structure may be shortened considerably compared to conventional practice.

From a further aspect, the present invention provides a liquefied hydrocarbon gas storage structure comprising a storage chamber having unlined concrete walls.

It will be understood that in the context of the present invention, the term "unlined" means that no hydrocarbon gas impermeable liners are provided over a substantial part of the height of the concrete walls.

As the walls of the storage chamber are unlined, the construction schedule for the structure may again be shortened considerably compared to conventional practice.

Preferably, the storage structure has an inner unlined concrete wall and an outer unlined concrete wall. Thus, the inner and outer walls form respective inner and outer storage chambers which can provide primary and secondary containment respectively so improving the effectiveness of the storage structure.

Advantageously, the storage structure may be used either onshore or offshore.

Preferably the inner and outer concrete walls are post-

- 5 -

tensioned cylindrical walls formed by slipforming. This provides a form of structure which is both fast and economic to construct compared to known storage structures.

5

The storage structure preferably further comprises a base made up of a concrete slab and a polymeric liner. As the base does not include steel liners as in the prior art, its construction is greatly simplified.

10

The liner is preferably a polyester and still more preferably the liner comprises a polyethylene terephthalate material such as Mylar™. Such a liner has the advantage that it acts as a barrier to both liquefied hydrocarbon gas and moisture as well as providing a sliding surface to allow the inner wall which forms the inner storage chamber to move relative to the outer wall.

15

20

The storage structure preferably further comprises a roof which is erected after the construction of the concrete walls.

25

Preferably, the roof comprises a main structure which spans across the space inside the inner concrete wall, and a subsidiary structure covering the space between the inner and outer walls which is constructed during and/or after erection of the main roof structure.

30

The structure preferably further comprises insulating material for insulating the liquefied hydrocarbon gas from the external environment in use, wherein the insulating material is coated with a polymeric substance to protect it against ingress of moisture and subsequent degradation. The use of such coated insulating material has the advantage that the insulation can be placed in the structure before the roof has been erected. This is

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in contrast to prior art structures in which the insulation must be installed in a controlled dry environment thus resulting in an increased construction time.

5

Preferably the inner wall is free to move relative to the outer wall in a direction substantially perpendicular to the walls.

10 This aspect of the invention is believed to be novel and inventive in its own right and so, from a further aspect, the present invention provides a liquefied hydrocarbon gas storage structure comprising an inner storage chamber arranged within an outer storage  
15 chamber, wherein the inner storage chamber is free to move relative to the outer storage chamber in a substantially horizontal direction. This has the advantage that the forces exerted on the structure's foundations for example in an earthquake situation would  
20 be substantially reduced so that the foundations do not need to be as strong as in prior art structures thus further reducing construction time and costs.

25 Preferably the inner wall is able to move relative to the base and so a joint is formed between the inner concrete wall and the base by means of a connecting plate connected to the inner concrete wall at one end and to an expansion joint at the other end, and wherein the expansion joint is attached to the base.

30

Where there is an interface between steel or other metallic or plastic materials and concrete in the structure it would be possible for liquefied hydrocarbon gas to leak out as this interface would provide a  
35 preferential flow path for the gas. Preferably therefore a baffle plate extends upwardly from the connecting plate around and/or into the inner concrete

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wall to act as a barrier to leakage of liquefied hydrocarbon gas at the junction of the inner concrete wall and the base.

- 5 This aspect of the invention is also considered to be novel and inventive in its own right and so from a further aspect the invention provides a liquefied hydrocarbon gas storage structure comprising an unlined concrete wall joined to a concrete base, wherein a  
10 connecting plate is provided to join the concrete wall to the concrete base and a baffle plate extends upwardly from the connecting plate around and/or into the concrete wall to act as a barrier to leakage of liquefied hydrocarbon gas at the junction of the wall  
15 and the base.

Still more preferably, two or more baffle plates are provided to enhance the barrier against liquefied hydrocarbon gas leakage.

- 20 Still more preferably, the baffle plates together with the connecting plate form an annular trough which surrounds the foot of the concrete wall.

- 25 Still more preferably, a recess is formed in the base of the structure in which the outer concrete wall is received and the recess is filled with grout to fix the outer wall against radial translation relative to the base. The recess is preferably not filled with grout  
30 until after the structure has been post-tensioned.

- Preferably, the liquefied hydrocarbon gas storage structure is filled with water prior to use in order to decrease the permeability of the concrete thereof by  
35 autogenous healing. This has the advantage that the process of hydrotesting which may be a safety requirement in some countries can be used to improve the



performance of the storage structure.

From a further aspect, the invention provides a method of constructing a liquefied hydrocarbon gas storage  
5 structure having inner and outer unlined concrete walls, wherein the inner and outer walls are formed by slipforming. By forming the walls by slipforming in this way, the structure can be built much more quickly and cost effectively than prior art structures.

10 Preferably, the walls are formed simultaneously so as to further speed up the construction process.

Preferably the structure further comprises a roof and  
15 the roof is erected after the construction of the inner and outer concrete walls. This is made possible due to the fact that the concrete walls are unlined such that the walls can be completed before the roof is erected. This leads to a further reduction in the time and costs  
20 involved in building the structure.

Preferably, the roof comprises a main structure which spans across the space inside the inner concrete wall, and a subsidiary structure covering the space between  
25 the inner and outer walls which is constructed during and/or after erection of the main roof structure.

Still more preferably the base of the outer concrete wall is formed in a recess in the base of the structure  
30 such that it is free to slide during construction. The recess is preferably filled with grout on completion of the structure such that the base of the outer concrete wall is fixed against radial movement. Still more preferably, this is not done until after the structure  
35 has been post-tensioned. This provides a simple and cost effective way of allowing the base of the outer wall to move during construction thus allowing the post-

tensioning applied to be effective all the way to the base of the wall while fixing the wall in position against radial translation once construction has been completed.

5

Preferred embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

10 Figure 1 shows an embodiment of an offshore LNG storage tank according to the invention;

Figures 2a to 2g schematically show the construction sequence for the offshore LNG storage tank of Figure 1;

15

Figure 3 is a sectional view through an onshore LNG storage tank according to a second embodiment of the invention;

20 Figure 4 is a detail of the part marked A in Figure 3; and

Figure 5 is a detail of the part marked B in Figure 3.

25 Figure 1 shows an offshore LNG storage tank according to a first embodiment of the invention. This tank is one of two 125,000m<sup>3</sup> storage tanks which when used together are suitable for a 4bcm/year sendout facility and which are designed to be installed in 18m water depth. It  
30 will however be appreciated that a tank of the design shown could have different dimensions. This design of tank satisfies BS7777 and the requirements of full containment tanks to EN1473.

35 As shown, the tank 1 comprises an inner unlined post-tensioned concrete wall 2 and an outer unlined post-tensioned concrete wall 4. The tank walls form inner

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and outer cylindrical storage chambers 3,5 and are slipformed from normal density concrete with a characteristic cube strength of 50MPa. The maximum water/cement ratio of the concrete allowed is 0.45. The concrete design is based on BS8110. The typical permeability of the concrete which should be achieved is approximately  $10^{-18} \text{m}^2$ .

An insulation layer 6 of perlite is provided between the inner 2 and outer 4 tank walls. This insulates the LNG which is stored in the inner storage chamber 3 at around  $-160^{\circ}\text{C}$  from the external atmosphere so as to reduce the boil-off rate of the stored LNG.

A concrete slab 8 extends across the base 7 of the inner storage chamber 3 and an insulating layer 10 of foamglas<sup>RTM</sup> is provided below this. A polyurethane foam layer 12 is provided below the foamglas layer 10 and, as shown, the polyurethane foam extends out to the inner edge 11 of the outer storage chamber and is bent upwardly to extend up along the inner edge of the lower part of the cylindrical wall 4 of the outer storage chamber 5.

As shown, the outer cylindrical wall 4 which forms the outer storage chamber 5 extends below the base 7 of the inner storage chamber 3 formed by the concrete slab 8, foamglas layer 10 and polyurethane liner 12, until it reaches the seabed 14. The space 13 provided inside the outer cylindrical wall 4 and below the inner storage chamber 3 is honeycombed to provide a number of chambers 15 each containing seawater. Further annular ballast chambers 15a and 16 are provided externally of the outer storage chamber. The ballast chambers 15 and 15a extend up to the height of the base of the inner storage chamber 3 and contain sea water. The ballast chambers 16 are provided above the external chambers 15a and

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contain rock 17 or other solid ballast if necessary to ballast the LNG storage structure to the seabed to overcome the uplift force developed when the LNG tank is empty.

5

The roof 18 of the tank shown in Figure 1 comprises a single span extending from the upper edge of the outer cylindrical wall 4. An insulation layer 20 of mineral wool is provided below the roof to reduce the boil-off rate of the stored LNG.

10

The construction sequence of a storage tank as shown in Figure 1 will now be described with reference to Figures 2a to 2g. The tank would normally be constructed in a purpose-built casting basin (not shown) as few ship docks exist with adequate width and at a sufficiently low rental to permit economic construction.

15

The cost of constructing such a casting basin can be incurred without affecting the viability of an offshore project. In most countries of the world, sites can be found that have access to at least 12m water depth, the channel draught needed for Panamax tanker access, without requiring extensive dredging.

20

In constructing the casting basin, the site is excavated to a level approaching that of the dredged channel, dewatering is installed and surface preparation carried out for areas that carry construction traffic during the construction process. The construction sequence described below has been developed to ensure that the earliest possible start is given to the construction of the tank superstructure.

25

As shown in Figure 2a, once the casting basin has been constructed, the lower walls making up the honeycombed space 13 below the inner storage chamber are constructed

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by slip forming. This is completed at about eight months into the design and construction schedule.

5       Next the lower part of the outer cylindrical wall 4 and the base 7 of the inner storage tank 3 are constructed in the tank wall starter construction phase over a period of approximately four months as shown in Figure 2b.

10       Then the inner and outer cylindrical walls 2,4 are constructed simultaneously using slipforming. A typical rate of wall climb achieved with this form of construction is 75mm/hour. The walls are then post tensioned (not shown). To do this, strand is threaded  
15       through ducts placed within the concrete during slipforming. Some of the wall post-tensioning can be carried out while the roof is being assembled. However, the post-tensioning of the inner cylindrical wall 2 should be completed before the roof 18 is raised.

20       Figure 2d shows the roof 18 in position within the walls ready to be raised. The roof is raised to the top of the walls 2,4 using air lift produced by fans as is known in the art. After the roof has been raised or  
25       while it is being raised, bridging sections 19 (as shown in Figure 2e) are inserted between the main body of the roof 18 (which ends at the inner cylindrical wall 2) and the outer cylindrical wall 4.

30       It is often a requirement that the LNG tank be hydro tested after construction to ensure that the permeability of the concrete walls is sufficiently low. Thus, a period of one month can be allowed in the  
35       construction schedule for hydrotesting. As shown in Figure 2e, the inner storage chamber 3 is filled with water 21 to carry out the hydrotesting process.

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It has been found that the hydrotesting process has the beneficial effect of healing cracks in the concrete therefore reducing its permeability and this is referred to as autogenous healing. If required, this autogenous healing can be used as a way of improving the containment characteristics of the tank. The insulation of the tanks is then completed after hydrotesting.

Using the method of construction described, the mixing of wet trades with outfitting trades is avoided apart from for the post tensioning operations. The outfitting of the tank is carried out once the roof has been raised (see Figure 2f).

The overall schedule from the start of detailed design to sailaway of the tanks has been assessed to be 24 months. After the tanks are installed on the seabed 14, the Regassification facilities 23 are floated over into position between the two tanks 1 as shown in Figure 2g, and hook-up, commissioning and cooldown are carried out over a period of about four months. In contrast to this, the prior art best practice for constructing an onshore LNG storage tank is 30 months and a schedule of 33 to 36 months is more typical. It is envisaged that an onshore LNG storage tank incorporating the features of the tank of Figures 1 and 2 could be constructed and operational within 21 months of the start of detailed design, which is a saving of 9 months on the prior art best practice. Such schedule savings deliver considerable net present value gains in addition to the capital cost savings they offer.

An alternative embodiment of an LNG storage tank according to the invention is shown in Figure 3. The same reference numbers have been used for elements corresponding to those of Figure 1. Further, the time savings provided by the tank design of Figures 1 and 2

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are also provided by this alternative tank design. As can be seen, the tank structure is similar in broad terms to that shown in Figure 1. However, the storage tank is intended to be used onshore rather than offshore and so there are some differences in the structure.

Figure 3 shows a section through the alternative storage tank. As shown the tank again has inner and outer unlined cylindrical concrete walls 2,4 with expanded perlite insulation 6 provided between the walls. The roof 18 is also similar in structure to that of the first described embodiment and is made up of steel segments which extend across the top of the inner storage chamber 3 and which are raised into position by upwardly exerted air pressure.

The base 7 of the tank is made up of a first concrete slab 24 extending over the base of the inner storage container. A sheet of Mylar™ 22 produced by Dupont is provided below the concrete slab 24 and extends out to the inner edge 11 of the outer cylindrical wall 4 and extends up the inner edge of the wall to a height of several metres above the base 7 (where the total height of the storage chamber is 38m). This provides a thermal guard at the lower corner base of the outer cylindrical wall 4 which is useful as this is the part of the storage tank which would experience excessive cracking in a spill condition and the thermal guard would have the effect of reducing the thermal gradient in the lower corner region, thus protecting it against high stresses which could lead to failure.

A layer of plywood 43 is provided above the Mylar liner 22 to protect it from damage.

35

A second concrete slab 26 is then arranged below the Mylar liner 22. The liner 22 acts as a barrier to LNG

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and moisture vapour and also isolates the lower concrete slab 26 from the cryogenic temperature of the LNG in the storage chamber. This protects the concrete slab 26 from cracking due to extreme temperature differentials across it and so reduces the risk of LNG leaking out from the concrete slab. To protect the soil from freezing, base heating can be provided in the concrete slab 26. However, any heat reaching the LNG in the storage chamber would increase the boil-off rate of the LNG from the tank and this is clearly undesirable. Thus, in an alternative embodiment, an undercroft (not shown) can be provided underneath the base slab 26.

A further feature of the Mylar liner 22 is that it provides a slip surface for movement of the inner wall 2 and base slab 24 as will be discussed further below.

Although not shown in Figure 3, a layer of foam insulation is provided between the Mylar liner 22 and the lower concrete slab 26. The insulation is coated in an impermeable substance to protect it from moisture ingress and subsequent degradation. The use of coated insulation as described has the advantage that the insulation can be laid in the base 7 before the roof 18 has been constructed. This is in contrast to the insulation used in prior art storage tanks in which metallic liners are used to protect the insulation against moisture and the insulation can only be laid once the walls and roof of the tank have been assembled to provide a sheltered working environment.

A detail of an upper corner joint of the tank of Figure 3 is shown in Figure 4. As shown, the main roof structure 18 is made up of metal segments 28 which span to the inner cylindrical wall 2 and are held in place by a ring girder 30. The roof structure is then completed between the outer and inner cylindrical walls 2,4 by



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bridging portions 19 and construction joints 32 are provided to allow the outward thrust of the weight of the roof to be keyed in to the bridging portion 19. The inner storage chamber 3 provided in the tank is  
5 insulated from the roof cavity by a layer of insulating material 34 provided above aluminium decking 36.

Figure 5 shows a detail of a lower corner joint of the tank of Figure 3. As shown, a recess 37 is provided in  
10 the reinforced concrete base slab 26. This allows the outer cylindrical wall 4 to slide relative to the base during construction. On completion of construction, the base of the outer wall is fixed against radial movement by filling the recess 37 with grout 39 as shown.

15 Another important feature of the structure is that the Mylar liner 22 acts as a sliding surface so that the inner cylindrical wall 2 and base slab 24 can slide relative to the lower concrete slab 26 and the  
20 foundations. This has the consequent advantage that the inner storage chamber 3 would move separately from the rest of the storage tank in an earthquake situation which reduces the forces required to be borne by the foundations and hence reduces the overall construction  
25 costs for the tank.

The joint provided between the inner cylindrical wall 2 and the upper concrete slab 24 allows the inner wall 2 to slide radially and is provided by two steel rings 38  
30 cast into the concrete slab and to which respective ends of an expansion joint 40 which is typically semicircular in section are attached. An annular steel connecting plate 42 extends between the outer end of the expansion joint 40 and the cylindrical wall and is cast into the  
35 cylindrical wall to be fixed to it. The connecting plate 42 is also fixed to the concrete slab by means of a further steel ring 41 which is cast into the slab and

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to which the connecting plate is attached.

Two cylindrical steel baffles 45 are provided on the connecting plate 42 extending upwardly therefrom and being radially spaced from each other. The baffles 45 are welded to the connecting plate 42 so as to form an annular "boot" which surrounds the foot of the inner cylindrical concrete wall 2 so that the baffles 45 abut against the respective inner and outer faces of the foot of the wall. The baffles advantageously act as barriers to LNG leakage at the interface of the connecting plate 42 and the base of the inner cylindrical concrete wall 2 by breaking the preferential flow path for LNG provided at the interface between the base and the wall.

In an alternative embodiment (not shown) one or more, preferably three, radially spaced steel baffles extending vertically upwardly from the connecting plate 42 are cast into the concrete cylindrical wall 2. In this embodiment, the baffles forming a "boot" external of the wall are not required.

The tank of figures 3 to 5 is intended to be used onshore. However, many of the features thereof could equally well be applied to offshore tanks such as the tank of figures 1 and 2. Thus, for example, the tank of figures 1 and 2 could have a base including a Mylar liner which is constructed as shown in Figure 3.

It will be appreciated that the storage structures described above are preferred embodiments only of the invention and that various modifications could be made to them which would fall within the scope of the invention as claimed. Thus for example, the base of the storage structure need not include a polymeric liner as described but could be made of unlined concrete.

Claims

1. A liquefied hydrocarbon gas storage structure comprising a storage chamber having unlined concrete walls.  
5
2. A liquefied hydrocarbon gas storage structure as claimed in claim 1, the structure comprising an inner unlined concrete wall and a second outer unlined concrete wall.  
10
3. A liquefied hydrocarbon gas storage structure as claimed in claim 1 or 2, wherein the inner and outer concrete walls are post-tensioned cylindrical walls formed by slipforming.  
15
4. A liquefied hydrocarbon gas storage structure as claimed in claim 1, 2 or 3, further comprising a base made up of a concrete slab and a polymeric liner.  
20
5. A liquefied hydrocarbon gas storage structure as claimed in claim 4, wherein said liner is a polyester.
6. A liquefied hydrocarbon gas storage structure as claimed in claim 5, wherein said liner comprises a polyethylene terephthalate material such as Mylar<sup>TM</sup>.  
25
7. A liquefied hydrocarbon gas storage structure as claimed in any of claims 2 to 6, further comprising a roof which is erected after the construction of the concrete walls.  
30
8. A liquefied hydrocarbon gas storage structure as claimed in claim 7, wherein the roof comprises a main structure which spans across the space inside the inner concrete wall, and a subsidiary structure covering the space between the inner and outer walls which is  
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constructed during and/or after erection of the main roof structure.

5 9. A liquefied hydrocarbon gas storage structure as claimed in any preceding claim, the structure further comprising insulating material for insulating the liquefied hydrocarbon gas from the external environment in use, wherein the insulating material is coated with a polymeric substance to protect it against ingress of  
10 moisture and subsequent degradation.

10 10. A liquefied hydrocarbon gas storage structure as claimed in any of claims 2 to 9, wherein the inner wall is free to move relative to the outer wall in a  
15 direction substantially perpendicular to the walls.

20 11. A liquefied hydrocarbon gas storage structure as claimed in any of claims 4 to 10, wherein a joint is formed between the inner cylindrical wall and the base by means of a connecting plate connected to the inner concrete wall at one end and to an expansion joint at the other end, and wherein the expansion joint is attached to the base.

25 12. A liquefied hydrocarbon gas storage structure as claimed in claim 11, wherein a baffle extends upwardly from the connecting plate around and/or into the inner concrete wall to act as a barrier to leakage of  
30 liquefied hydrocarbon gas at the junction of the inner concrete wall and the base.

35 13. A liquefied hydrocarbon gas storage structure as claimed in claim 12, wherein a plurality of baffles are provided extending upwardly from the connecting plate around and/or into the inner concrete wall.

14. A liquefied hydrocarbon gas storage structure as

claimed in claim 13, wherein the baffles and connecting plate form an annular trough which surrounds the foot of the inner concrete wall.

5     15. A liquefied hydrocarbon gas storage structure as claimed in any of claims 4 to 14, wherein a recess is formed in the base of the structure in which the outer concrete wall is received, and the recess is filled with grout to fix the outer wall against radial movement  
10     relative to the base.

16. A liquefied hydrocarbon gas storage structure comprising an inner storage chamber arranged within an outer storage chamber, wherein the inner storage chamber  
15     is free to move relative to the outer storage chamber in a substantially horizontal direction.

17. A liquefied hydrocarbon gas storage structure comprising an unlined concrete wall joined to a concrete  
20     base, wherein a connecting plate is provided to join the concrete wall to the concrete base and a baffle extends upwardly from the connecting plate around and/or into the concrete wall to act as a barrier to leakage of liquefied hydrocarbon gas at the junction of the wall  
25     and the base.

18. A liquefied hydrocarbon gas storage structure as claimed in claim 17, wherein a plurality of baffles extend upwardly from the connecting plate around and/or  
30     into the concrete wall.

19. A liquefied hydrocarbon gas storage structure as claimed in claim 18, wherein the baffles and connecting plate form an annular trough which surrounds the foot of  
35     the concrete wall.

20. A method of constructing a liquefied hydrocarbon

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gas storage structure as claimed in any preceding claim, wherein the concrete storage chamber is filled with water prior to use in order to decrease the permeability of the concrete by autogenous healing.

5

21. A method of constructing a liquefied hydrocarbon gas storage structure having inner and outer unlined concrete walls, wherein the inner and outer walls are formed by slipforming.

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22. A method as claimed in claim 21, wherein the inner and outer walls are formed simultaneously.

15

23. A method as claimed in claim 21 or 22, wherein the structure further comprises a roof and the roof is erected after the construction of the inner and outer concrete walls.

20

24. A method as claimed in claim 23, wherein the roof comprises a main structure which spans across the space inside the inner concrete wall, and a subsidiary structure covering the space between the inner and outer walls which is constructed during and/or after erection of the main roof structure.

25

25. A method as claimed in any of claims 21 to 24, wherein the base of the outer concrete wall is formed in a recess in the base of the structure such that it is free to slide during construction.

30

26. A method as claimed in claim 25, wherein the recess is filled with grout on completion of the structure such that the base of the outer concrete wall is fixed against radial movement.

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27. A method of installing a liquefied hydrocarbon gas storage structure as claimed in any of claims 1 to 15

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for use offshore, wherein the structure is installed on the seabed and regassification facilities are then floated into place over the structure.

- 5      28. A liquefied hydrocarbon gas storage structure comprising an unlined concrete storage chamber.
- 10      29. A liquefied hydrocarbon gas storage structure or method of constructing a liquefied hydrocarbon gas storage structure as claimed in any preceding claim, wherein the structure is for storing liquefied natural gas.

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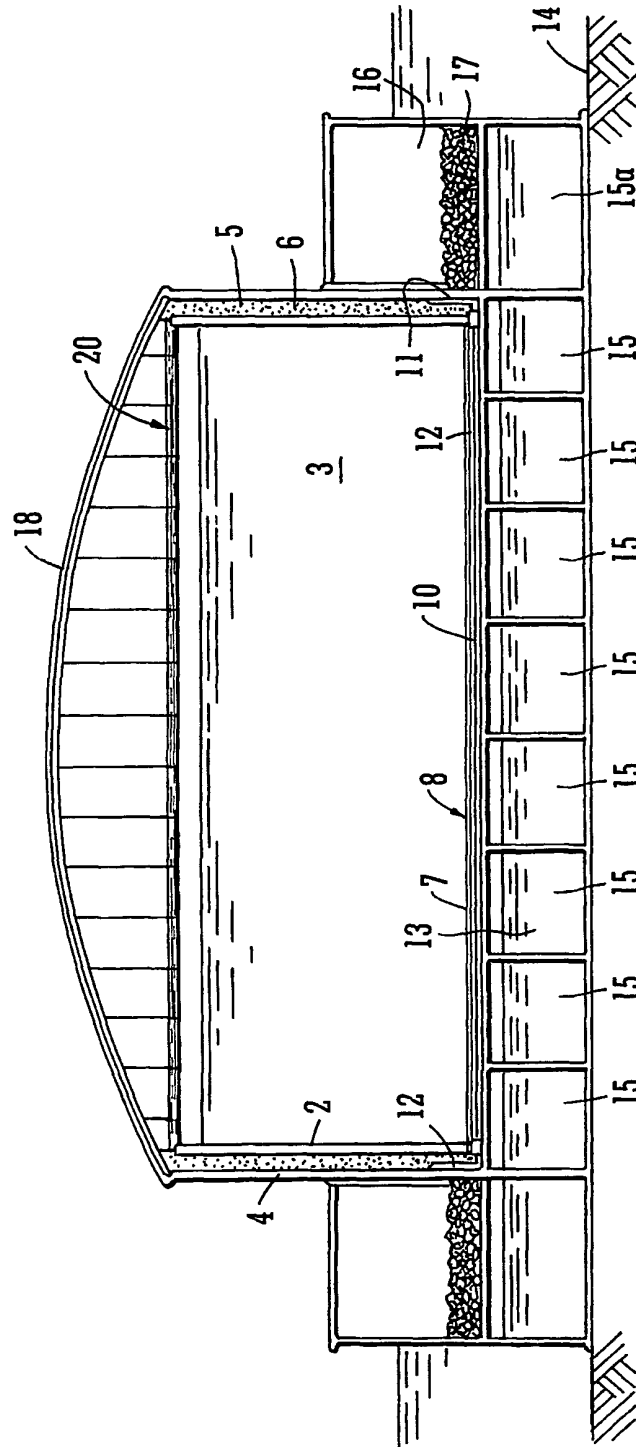


FIG. 1



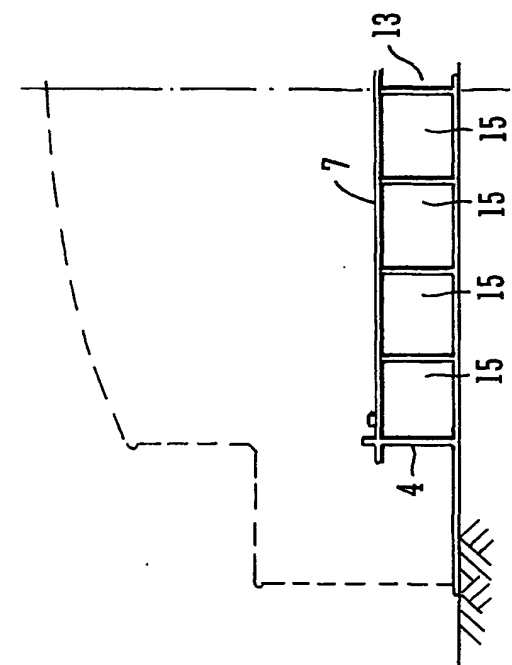


FIG. 2a

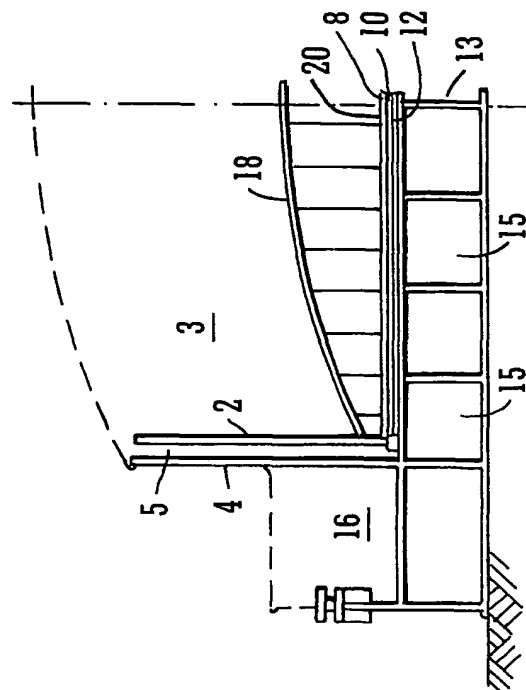


FIG. 2b

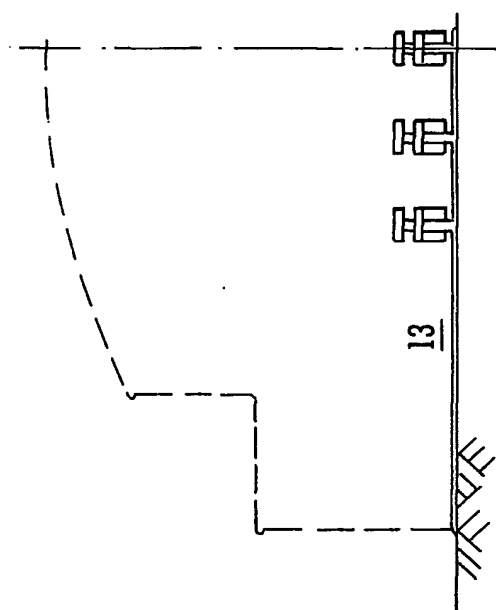


FIG. 2c

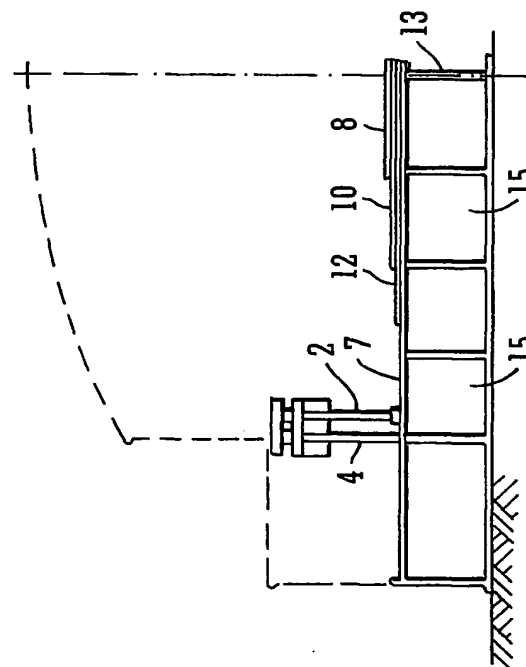


FIG. 2d

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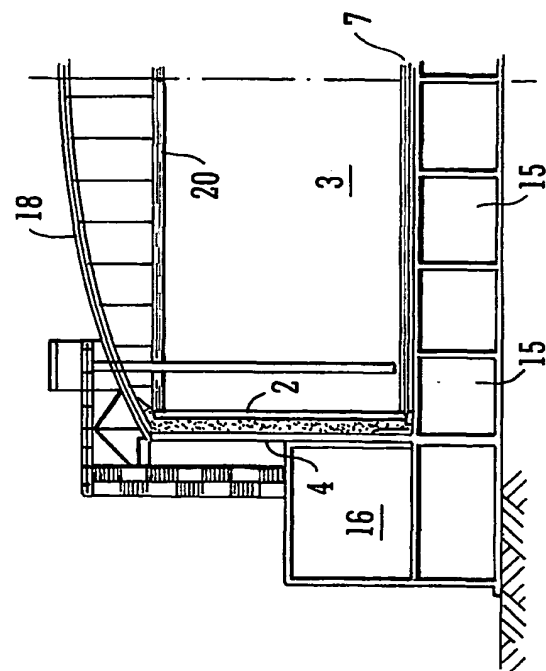


FIG. 2f

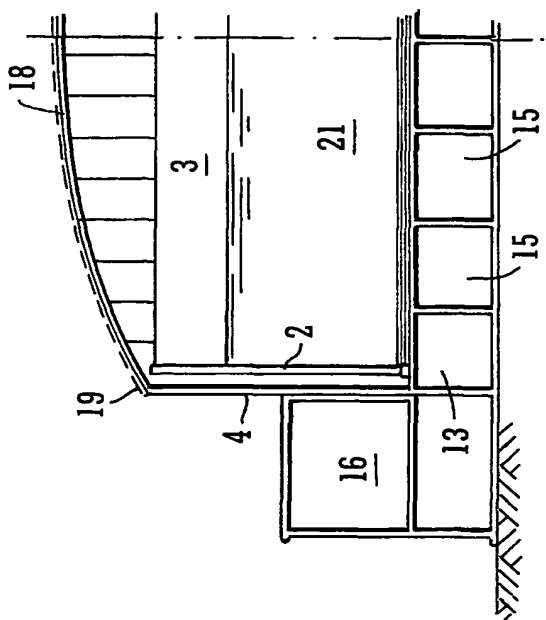


FIG. 2e

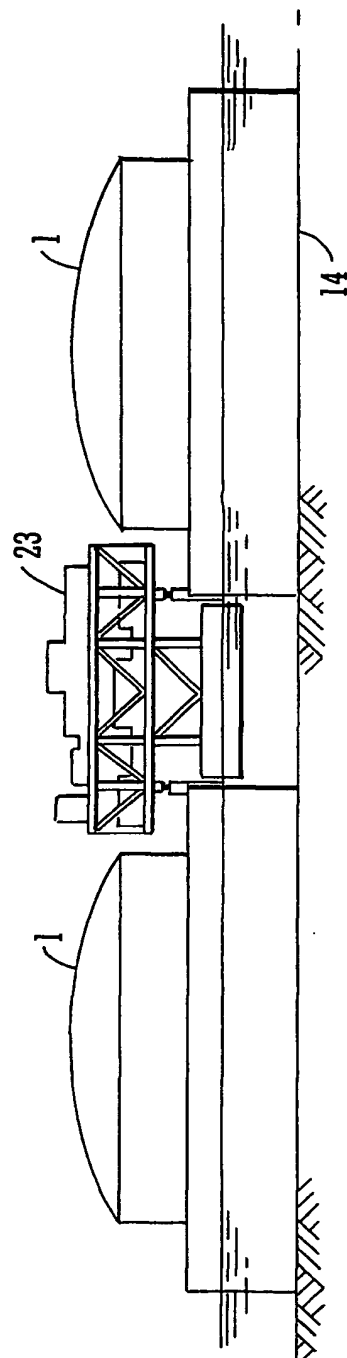
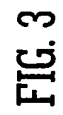


FIG. 2g



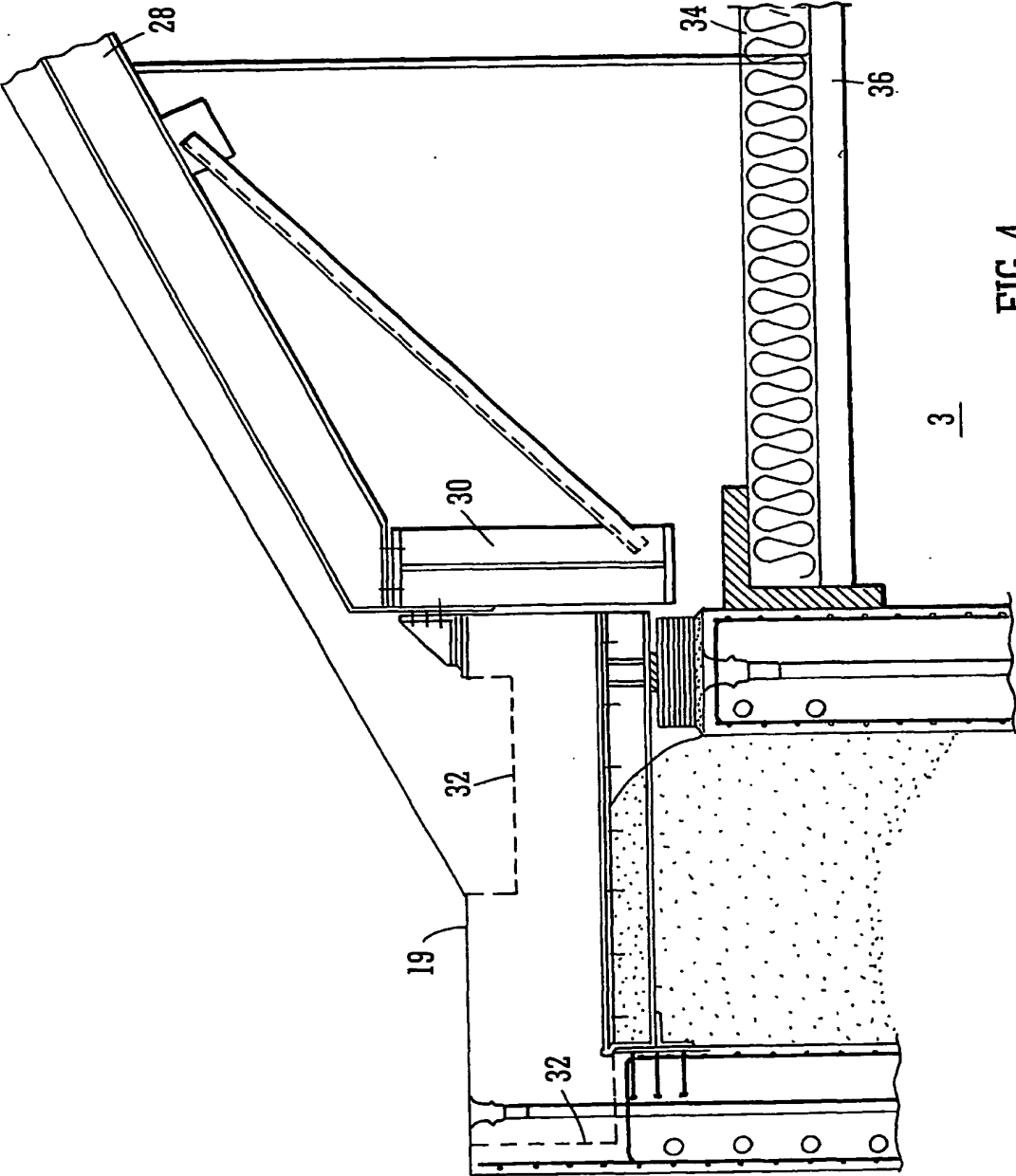


FIG. 4

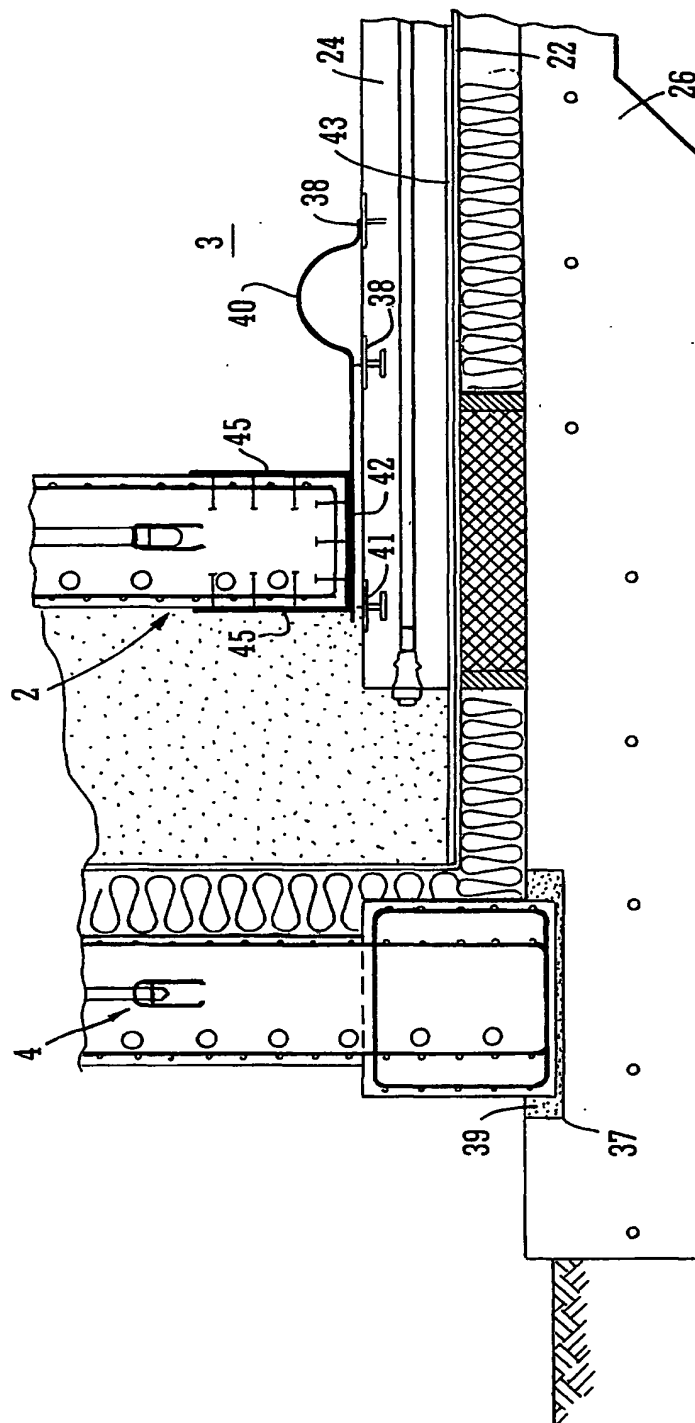


FIG. 5

## INTERNATIONAL SEARCH REPORT

PCT/GB 01/05587

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F17C3/02 E04H7/18

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F17C E04H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## Special categories of cited documents:

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- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- \*G\* document member of the same patent family

Date of the actual completion of the international search

14 March 2002

Date of mailing of the international search report

21/03/2002

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PCT/GB 01/05587

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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